Strategies to Control Streambed Degradation
Salt Creek Basin, Lincoln, Nebraska
September 2002

AUTHORITY: Section 22 of the Water Resources Development Act of 1974, as amended. This report was prepared for the City of Lincoln by the Omaha District, Corps of Engineers, Hydrologic Engineering Branch.

PROJECT AREAS

- Beal Slough – 48 St. to Salt Creek, covering 3.4 stream miles
- Salt Creek – Pioneers Blvd. To O St., 3.4 miles.
- Deadmans Run – 56 St. to 14 St., 3.8 miles

SITUATION

Streams in the Lincoln area are experiencing bed degradation and higher peak flows due to previous channel improvements and urban land use. The City of Lincoln will explore options for controlling the degradation and slowing the increase in peak flows.

TASKS: The Omaha District considered various strategies for preventing channel degradation, starting with the following outline.

- Evaluate the costs and benefits, at a reconnaissance level, of requiring developments adjacent drainage ways to install measures to prevent the channel degradation.
- Examine a range of strategies including grade checks, bioengineering techniques, and limitations on impervious surface cover.
- Emphasis will be placed on measures that would maintain or enhance water quality and preserve habitat and natural systems.

RELATED PROJECTS/REPORTS

- Salt Creek Levees at Lincoln, NE, Reconnaissance Report, October 1990
- Salt Creek in Lincoln, NE, Section 205, (1995-1997)
- *Trends in Channel Gradation in Nebraska Streams, 1913-95*, U.S. Geological Survey, Water-Resources Investigations Report 99-4103
- *Beal Slough Stormwater Master Plan*, May 2000
- *Channel Stabilization of Dead Man's Run and Dead Man's Run Tributary*, Sept 2001

SITE INSPECTIONS: The Hydrologic Engineering Branch inspected these three stream reaches on 2 August 2002. The city gave a briefing to the Branch before and during the site visit.

OVERVIEW

Hydro Branch considers the off-channel issues as clearly separable from the actual channel problems. Remedial actions in the channel are straightforward, based on existing dimensions and slope trends. Flows into the streams from adjacent developments still will be confined by the channel configuration. In other words, in-channel measures are more important than adjacent land use when the existing channels are in a stage of significant degradation. Once the channel is restored to a reasonable degree of stability, modifications of inflow into the system would become a top priority.

OBSERVATIONS

The upstream area of the Beal Slough study reach has a bed width of 10 to 12 feet. In the vicinity of the power transmission tower (near 37 St.), the left bank is 9 feet high, while the right bank is 14 feet high. The banks are a gray soil comprising silt and clay. The bed is silty sand. Riprap from the tower bank has scattered itself into the channel. The banks are near vertical, and evidently are being cut by stream erosion.

Significant degradation is apparent in the lower stretch of Beal Slough. On the upstream side of the West Pioneers Boulevard bridge, the landowner has undertaken a major bank protection effort, covering the left bank with broken concrete. The steep banks in this area are 20 feet high. This bridge actually is a set of box culverts, which provide grade control. The stream drops about 2 feet from these bridge culverts.

The stream just below Pioneers Boulevard (and downstream of two railroad bridges) has 20-foot eroding banks. The bed is silty sand, while the banks are clay and silt. The pools are habitat for minnows and frogs. Mature trees line Beal Slough, and willows are common on the low benches.

The USGS channel gradation trend study showed that Beal Slough downstream of 40th Street has dropped between 3.6 and 9.2 feet since 1961. The average change at the surveyed locations is 6.8 feet.

Most of the Deadmans Run channel in the study reach has been armored along its bed and banks. The streambed is covered with a concrete filled mat (possibly referred to as a Reno mattress). Gabions extend halfway up the banks. The 15-foot wide channel is about 15 to 20 feet below the top of the banks.

Although the armored stretches of the channel are rigidly protected, the bed still shows signs of degradation. The mattress sections are about 150 feet long, and there is a drop of a few inches from one section to the next. At the 48th Street bridge, the concrete apron at the downstream side has broken from the concrete sill beneath the bridge, so that it tilts downstream. The water in the plunge pool was 20 inches lower than the bridge sill. This area begins a stretch where the stream is natural, with no systematic armoring. Streambed deposits from the old channel are 12 feet up in the right bank, showing the extent of long-term bed degradation. The stream is about 20 feet wide here, and the banks are nearly vertical.

The study reach for Salt Creek (Pioneers to O St.) does not show the degradation conditions that are seen on Beal Slough and Deadmans Run. Although it is confined by levees, the channel is wide, with a primary channel and sandbars. Grass covers the low-slope banks, and toe erosion was minimal. Our conclusion, therefore, is that stream protection or remediation should concentrate on Beal Slough and Deadmans Run, without any significant study effort on Salt Creek

OFF-CHANNEL TREATMENTS

The basic concept for reducing the effects of inflows on stream degradation is to spread the inflow over more time. This reduces the height of the stream's flow peaks. Since higher stream flows have higher erosive energy, the stream is more stable when flows are moderated. The initial means of controlling peak flows is to limit the amount of impervious surface cover (roofs, walks, driveways). However, the landowners' intended use of their property often doesn't leave much flexibility in minimizing roofs and pavement. Thus, the first effective control of runoff typically would be detention ponds. Outside of small detention basins on individual parcels, the ponds would be incorporated into the drainage way (either as widened areas in the stream, or as off-channel storage).

The Beal Slough Master Plan compiled land use data for that stream, and discussed options for off-channel treatments. We concluded that the Master Plan document gave thorough coverage to those drainage options. In fact, the general concepts presented for Beal Slough can be transferred to the Deadmans Run and Salt Creek corridors. [EXPAND DISCUSSION, if possible].

EVALUATION

A. Salt Creek: This creek appears to be stable, and thus was set aside in our analysis of degradation control measures

B. Beal Slough

This stream is in need of major work to address degradation. The city already has moved forward with corrective measures, such as the wetland project that was recently built upstream of 40th Street. In addition, the master plan specified placement of nine grade control structures between 27 Street and the Burlington Northern bridge. However, the bed degradation documented by the USGS study referenced above suggests that more grade control is needed.

The intent of the grade control measures is to hold the bed in place, and also to reduce the velocities and erosive energy. The nine structures specified in the Master Plan each are only a foot high. They will be adequate for reducing the bed degradation, but do not add enough height to correct for the existing high-slope channel. We recommend that several higher drop structures be installed. A maximum stone size of 18" would be a conservative, practical design specification. A grade control structure should have a thickness 50 percent greater than the D_{100}, so the proposed structures in Beal Slough would be 27 inches high. However, there may be consequences with higher water surface elevations, so the placement of grade control structures will need to be further evaluated.

The design concept is to install structures that will produce cumulative rises in the streambed greater than the documented degradation. This will break the stream's steep slope into a series of lower-slope segments. Thus, velocities and erosive energy should decrease. The 27-inch high structures will not be keyed into the bank. Therefore, half of the structure height ultimately could be lost as the stones settle into place. Furthermore, the irregular open face of stone structures translates into a lower effective height, relative to the upper edges of the stones. So, a conservative estimate of the effective drop is one-half of the nominal height. The actual effective drop thus is only about one quarter of the 27-inch structure thickness, or 6.75 inches.

As indicated above, we would not count the 9 low grade control structures against the documented bed drop. Twelve structures with a design thickness of 27 inches would provide a cumulative controlled drop equal to the 6.8 feet of past degradation. To further ensure that the new grade control is sufficient, we would add one more structure, to cover the possibility that localized conditions can make some reaches significantly more erodible than others. The proposed design locates the structures simply by spacing them equally along the study reach. This layout is shown on the attached drawing (Sheet 1). If the city moves forward with these proposed drop structures, the final spacing would be dictated by actual site conditions (e.g., to fit in with the existing riffle-pool spacing).

Each structure in the smaller channel of the upstream one-third of Beal Slough would need 30 tons of stone. In addition, refusals would be excavated into the high banks, with 9.3 cubic yards of excavation on each side. Each refusal would need 9.5 tons of stone. Each of the structures in the lower two-thirds of Beal Slough would take 50 tons in the channel, plus 19 tons for refusals. The total amount of stone for the 13 structures would be

4 x (30 + 19) + 9 x (50 +19) = <u>817</u> tons.

The total excavation for refusals is 13 x 2 x 9.3 = <u>242</u> cubic yards.

C. Deadmans Run

The channel armor in this stream probably is contributing to the overall instability in the Deadmans Run system. The bank armor prevents the channel from expending energy along any floodplain feature, and the Reno mattress provides minimal roughness. Also, the slope is steeper than a meandering channel would offer. Although there are some areas of the channel without the armor, those locations would be appropriate for future work (like wetland development) after remedies are applied to the armored reach.

A good indication of the magnitude of the degradation problem is the 7-8 foot deep headcut on the tributary entering Deadmans Run from the south (north of Holdrege, along 48th Street). Observations on Deadmans Run at 48th Street can be extrapolated to compare to the tributary information. The bed liner appears to drop about 3 inches at each seam between segments. There is a 5-inch drop leading to the bridge sill, and a 20-inch drop on the downstream side. However, there is a 2-inch layer of sand and small gravel on the bed liner at 39th Street (about Station –0+80). If the stretch below about 40th Street (approx. 4+00) is assumed to be non-degradational, the 3-inch drop per 150 feet of liner segment could be applied to the upstream part of the study reach (up to 56 Street, Sta. 70+00). This would include the 5-inch drop leading up to the 48th Street bridge, as follows:

5” + (7000-400) x 3”/150’ = 137” = 11.4 feet.

This could be compared to the observed drop of the tributary, applying the 137" to the reach between 48th (Sta. 34+50) and 40th Streets, and adding the 20-inch drop at the downstream side of the bridge sill.

$$(137+20) \times (3450-0400)/6600 = 72.6" = 6 \text{ feet.}$$

This estimate is a reasonable confirmation of the 7-8 foot degradation at the tributary.

The erosion problems on Deadmans Run are great enough that a combination of efforts will be needed. Thus, the pending grade control measures for the tributary (outlined in the Sept 2001 report) will reduce problems at the confluence. Similarly, that report specifies several intervention measures downstream of 48th Street.

Although the gabions form a secure, continuous wall along the channel, the Reno mattress in the bed looks like it could be modified by cutting out sections as might be appropriate. Stone could be piled into these cut-out areas, to form small drop structures. While stone structures in Beal Slough could cause the stream to flatten out between structures, such structures interjected into the lined bed on Deadmans Run would mostly just increase roughness. So although the current's energy can be reduced over the stone, the flow will return to the steep slope of the lined bed. Therefore, there isn't a direct formula for their design based on the documented degradation.

Working stone into every other section of bed liner should preserve the basic design of the armored channel, while providing frequent drop structures. The length of the cut-out for the stone would be twice the width, or 30 feet The effective part of the drop structure would be at the upstream end of the 30-foot retrofit, where the stone would be 10 inches above grade. A sheet pile (6-foot) would be driven at the downstream end of the cut-out, to prevent the flow from working under the downstream bed liner. The hole for the stone would be 2-feet deep, with a 4-inch layer of coarse gravel in the bottom. The stone would be only 4 inches above grade at the downstream end of the cut-out. These retrofits to the bed liner would be applied at eleven sites upstream of 48th Street, and at ten downstream sites. They are shown on drawing sheet 2.

Each retrofit of the bed armor will require 64 tons of stone, 5.6 c.y. of gravel, and 15 linear feet of 6-foot sheet pile. The cut-out will require about 33 c.y. of excavation, and the removed mattress would comprise 2 to 2½ cubic yards. The 21 retrofits therefore will involve the following quantities.

- Place 1344 tons of stone
- Place 118 c.y. of large gravel
- Excavate 693 c.y. of streambed
- Remove and dispose of 50 c.y. of Reno mattress
- Install 315 linear feet of 6-foot sheet pile

ALTERNATIVES

The no-action alternatives are not presented for Beal Slough or Deadmans Run. The city's recent reports (May 2000, September 2001) acknowledge the gravity of the existing conditions, and initiate corrective and preventive measures. Thus, the city has already gone beyond the no-action option.

The proposed set of stone grade control structures for Beal Slough basically expands on the design put forth in the Master Plan. An alternative means of reducing the flow velocity would be to increase the sinuosity, and possibly to incorporate wetlands for either additional roughness or as storage areas. Such measures typically are dictated by real estate constraints, and would fall more into the realm of the Master Plan's off-channel measures. So, they could be added as degradation control measures even where stone grade controls are placed. Thus, they are not actually an alternative to the grade control structures.

Drop structures could be built from sheet pile or anchored timber, but stone structures combine durability and a clean flow profile with the ability to self-adjust. Timber structures can catch enough debris to impede flood flows, and they are less durable than stone. Sheet pile isn't a major threat at building up debris, and it doesn't need to adjust if it is driven deep enough. However, it lacks the natural riverine character that stone and woody debris have. Also, it does not mimic a riffle-pool complex the way stone does. Thus, the stone grade checks are the preferred alternative on Beal Slough.

The natural character of Deadmans Run already has been compromised by the bed/bank armoring. Therefore, sheet pile would not be a significant environmental detriment there. Drop structures theoretically could be built with sheet pile without cutting out sections of liner. Such a design would use more than 21 sites, so that the individual drop wouldn't be excessive. A design employing sheet pile in lieu of stone would not, however, address the design goal of significantly adding roughness. Also, the potential for something similar to a riffle-pool system would end up being more of a washboard streambed. Nevertheless, if the stone retrofit is deemed impractical or too costly, the sheet pile method may be worth considering, to reduce some of the system's energy.

ATTACHMENTS

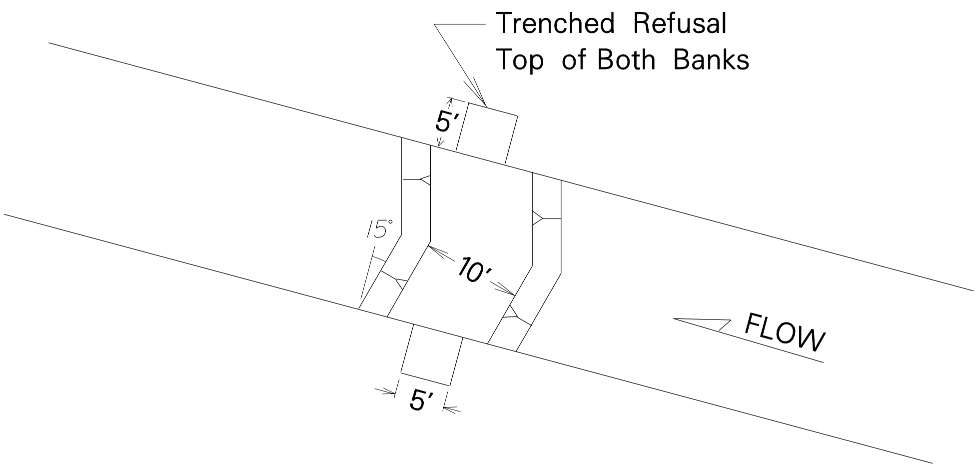
- Sheet 1 – Beal Slough
- Sheet 2 – Deadmans Run

PREPARER: ____________________ 19 Sep 2002
Jerry J. Tworek Sedimentation and Channel Stabilization Section

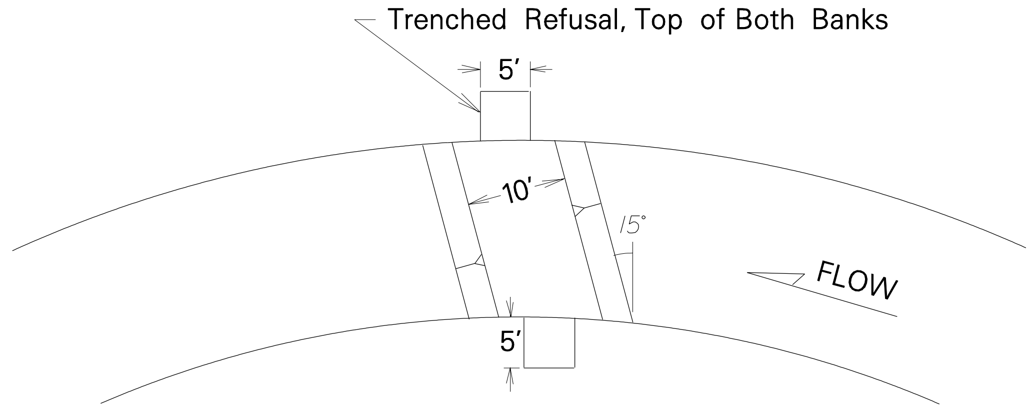
REVIEWED: ____________________ 23 Sep 2002
John W. Garrison Sed. and Chan. Stabil. Section

(minor revisions made after the 24 Sept 2002 meeting)

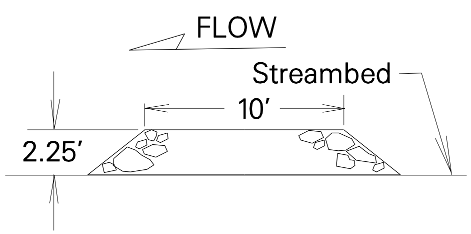
REVISIONS	SYMBOL	DESCRIPTIONS	DATE	APPROVED



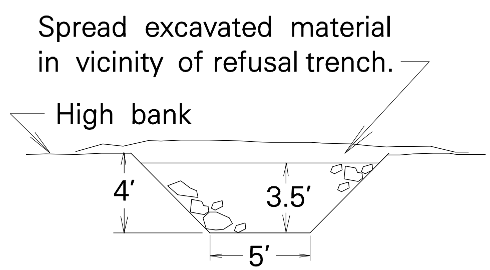
Typical Grade Control Structure, in Straight Reach
Plan View – Not to Scale



Typical Grade Control Structure, in Bend
Plan View – Not to Scale



Grade Control Structure
Cross Section – Not to Scale



Refusal at Grade Control Structure
Cross Section – Not to Scale

Proposed Grade Control Structure Locations (based on near–equal spacing).

193 + 00
(City's 9 new GC structures are between 184 + 15 and 164 + 90.)

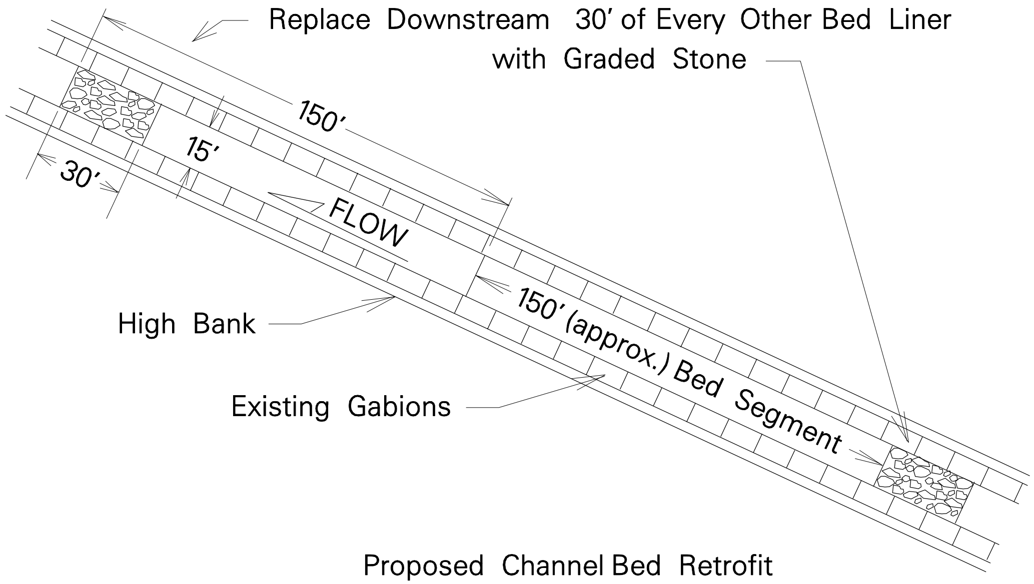
152 + 20	76 + 10
139 + 50	63 + 40
126 + 80	50 + 70
114 + 20	38 + 10
101 + 50	25 + 40
88 + 80	12 + 70

Notes:

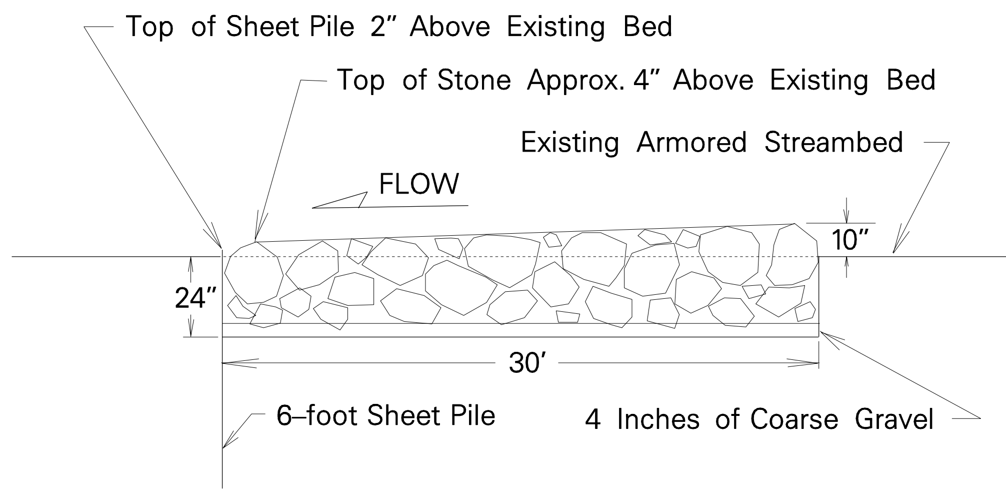
1. Place extra rock on the straight–reach grade control structures at the bank interface, to form a talus–type configuration.
2. The elevation of the outside bend of the grade control structures shall be six inches higher (i.e., 2.75 feet above the streambed) than at the inside bend.

Sheet No. 1	Computer File: LNCN2b Date: Sept. 2002 Drawing Code:	Spec. No. DACW45–03–B– Contract No. DACW45–03–C– LNCN2	U S ARMY ENGINEER DISTRICT CORPS OF ENGINEERS OMAHA, NEBRASKA HYDROLOGIC ENGINEERING BRANCH	**Beal Slough and Deadmans Run – Lincoln, Nebr.** **SECTION 22 STUDY** **Plan and Typical Cross Sections – Beal Slough**	Submitted by: Chief, Sediment and Channel Stabil. Sec.	Designed by: J. J. T. Checked by: J. W. G. Reviewed by: D. B. P. Drawn by: J. J. T.

REVISIONS	SYMBOL	DESCRIPTIONS	DATE	APPROVED



Proposed Channel Bed Retrofit
Plan View – Not to Scale



Proposed Channel Retrofit
Cross Section – Not to Scale

Approx. Station	Reach Limits	Channel Rehabilitation
70 + 00	56th & Holdrege	
		10 Proposed Stone Sections
34 + 75	48 Street	
		Recent Rehabilitation
8 + 90	42 Street	
		11 Proposed Stone Sections
–24 + 00	33 Street	

Sheet No.						
2	Computer File: LNCN2d Date: Sept. 2002 Drawing Code: LNCN2	Spec. No. DACW45–03–B– Contract No. DACW45–03–C–	U S ARMY ENGINEER DISTRICT CORPS OF ENGINEERS OMAHA, NEBRASKA HYDROLOGIC ENGINEERING BRANCH	**Beal Slough and Deadmans Run – Lincoln, Nebr.** **SECTION 22 STUDY** **Plan and Typical Cross Section – Deadmans Run**	Submitted by: Chief, Sediment and Channel Stabil. Sec.	Designed by: J. J. T. Checked by: J. W. G. Reviewed by: D. B. P. Drawn by: J. J. T.